TULIP—Overcoming Interoperability Testing Limitations

Charles S. Hyatt
Logicon, Incorporated, San Diego, California

Andrew Hannam
STASYS, Limited, Farnham, England

This paper discusses a process known as Through Life Interoperability Planning (TULIP), initially developed and used by the United Kingdom and currently in the early stages of adoption and implementation by the U.S. joint services. The TULIP process discovers and documents potential interoperability problems early in the development of tactical data systems, well before interoperability testing occurs and much less expensively than formal testing. It shows great promise as a means to overcome the inherent limitations of interoperability testing. The current TULIP development is specifically intended for application to tactical datalinks (TDLs), particularly Link 16, the standard Department of Defense TDL. However, because it is a process primarily carried out through systems analysis by subject matter experts and documentation and is not dependent on elaborate, expensive test systems, it could be applied to virtually any interoperability requirement.

The U.S. military and its North Atlantic Treaty Organization (NATO) and Pacific Rim allies use tactical datalinks (TDLs) extensively to exchange real-time tactical information about what is happening on the battlefield—land, sea, air and space. The TDLs also are used to coordinate and report offensive actions against the enemy, and immediate reactions to enemy threats. These data are time-critical; even a few seconds of delay in processing, interpreting, understanding or reacting can cost friendly lives. Therefore, units using TDLs require interoperability in its purest sense.

Identifying interoperability problems

The U.S. joint services have had a TDL interoperability testing program in operation for 30 years. All systems equipped with TDLs are required by the U.S. Department of Defense (DoD) to be certified for interoperability by the Joint Interoperability Test Command (JITC), Fort Huachuca, Arizona. DoD requires that systems be re-certified whenever a significant change is made to the tactical data system (TDS), or after a specified amount of time has elapsed since the last test. JITC employs an elaborate test system and a distributed testbed that cost well into the hundreds of millions of dollars to build, and tens of millions of dollars annually to operate and maintain.

The Navy Center for Tactical Systems Interoperability (NCTSI) performs certification testing prior to U.S. Navy systems being tested by JITC. Other services have similar test processes. Furthermore, most contracts for TDS development require some form of interoperability testing prior to government acceptance of the system.

Despite these rigid, expensive testing requirements, operational units continue to experience interoperability problems that hamper their operational effectiveness. This lesson has been hard-learned in the two most recent major U.S.-allied military actions—operations DESERT STORM and ALLIED FORCE. In fact, the U.S. interoperability testing program grew out of interoperability problems experienced during the Vietnam War.

There are several reasons why problems continue to exist despite rigid test requirements. Tight schedules driven by operational requirements for building and fielding systems sometimes make it infeasible to comply fully with the prescribed interoperability testing requirements. Unfortunately, but unavoidably, the axiom, "If you want it bad, you'll get it bad," often applies. The TDLs are extremely complex, requiring error-free exchange of tens of thousands of data items governed by thousands of protocols for their transmission, reception and use. The number of TDSs in the U.S. inventory, and in that of U.S. allies, is growing rapidly. The Joint Tactical Information Distribution System (JTIDS) and its TDL, known as Link 16, became fully operational in 1994.

Link 16, now the standard for nearly all tactical units, from the largest aircraft carriers, to the smallest fighters, represents a dramatic increase in TDL use, causing a major challenge to interoperability because of the greatly increased numbers of units and amount of information exchanged. To test the implementation of every single data item and protocol by every system, and the interactions between every possible combination of systems, would be too expensive in terms of time, money and manpower.

Interoperability certification testing amounts to a “final exam”—not taking place until a system is fully specified and coded, and often not until it is already installed in operational units. At this advanced development stage, it is more expensive to correct problems detected in testing, and many go uncorrected. The result of these inherent limitations on interoperability testing is that interoperability problems in a TDS, or between TDSs, often are not discovered until they are being used by the warfighters who are depending on them. A problem may not be discovered until a critical point in a military operation, causing potentially disastrous consequences.

Eliminating barriers to interoperability

To eliminate interoperability problems not found in testing, the United Kingdom has developed an inexpensive new process. The Through Life Interoperability Planning process, better known as TULIP, is now national policy of the U.K. Ministry of Defence, which requires that TULIP be applied to all new U.K. systems fitted with TDLs. U.S. joint services, led by the Air Force and Navy, are beginning to adopt the TULIP process. Other NATO and Pacific Rim allies either have adopted, or are considering adopting, the TULIP process.

TULIP seeks to overcome TDL interoperability testing limitations by having TDL experts perform detailed systems analysis and work with system developers from the initial system development stages. This identifies potential interoperability problems much earlier in development than interoperability testing normally would. It also identifies problems that might not be discovered by interoperability testing. The earlier a problem is discovered, the less expensive it is to fix. The relative cost of fixing problems at various development stages is shown in *Figure 1*, which was developed from data derived in an Institute for Electrical and Electronics Engineers study.

It must be emphasized that TULIP is a human *process*, not an automated turnkey panacea for all interoperability problems. The process depends on three principle ingredients:

■ **Subject Matter Experts** (SMEs) are systems analysts and computer scientists who have comprehensive knowledge of the TDL standards against which the systems are specified. They work with system developers from the time that planning begins to ensure requirements are understood and system specifications are written correctly.

■ **Documentation** of all known system deviations from the prescribed TDL standards serves both as a work list of deficiencies requiring correction, and as an aid to analyzing potential interoperability problems.

■ **Analysis** of the documentation to determine interoperability problems establishes priorities for correction, and informs the TDS operators of “workarounds” they should use until problems are corrected.

Note that none of the above principle ingredients requires expensive, time-consuming testing using sophisticated test systems, such as those employed by JITC and the individual military services. This does not mean that JITC testing is unnecessary. Quite the contrary—testing is absolutely essential. But the relatively inexpensive, uncomplicated TULIP process augments the interoperability testing process, thereby filling gaps and helping to ensure near-100-percent interoperability. Discovery and correction of many problems through systems analysis by TDL experts make the testing process simpler, shorter and less expensive by highlighting areas in which testing should concentrate.

The TULIP process

Figure 2 is an overview of the TULIP process. The following key elements constitute the TULIP process:

■ **SLIRS**—Single Link Interface Requirement Specification (for each TDL)

■ **PIDD**—Platform Implementation Difference Documents (for each TDL-equipped platform)

■ **IOM**—Interoperability Matrix

■ **IOAs**—Interoperability Assessments

For the TULIP process to support interoperability for all affected systems, an unequivocal, unambiguous baseline specification must define the TDL data items and protocols. The SLIRS serves this purpose. The U.S. joint SLIRS for Link 16 is under development and is based in large part on the U.K. Link 16 SLIRS. A SLIRS for Link 22, a multimedia long-haul TDL to augment Link 16 in the future, also will be developed. In addition, a Multilink IRS (MLIRS) will be developed to provide the rules for translating and forwarding data between the different TDLs. In the United States, military standards (MIL-STDs) for each TDL have existed for many years. NATO nations use standardization agreements (STANAGs) equivalent to MIL-STDs. However, these are subject to the many vagaries of any document written and maintained by a joint committee. Misinterpretation and lack of clarity of detailed requirements often have caused significant interoperability problems.

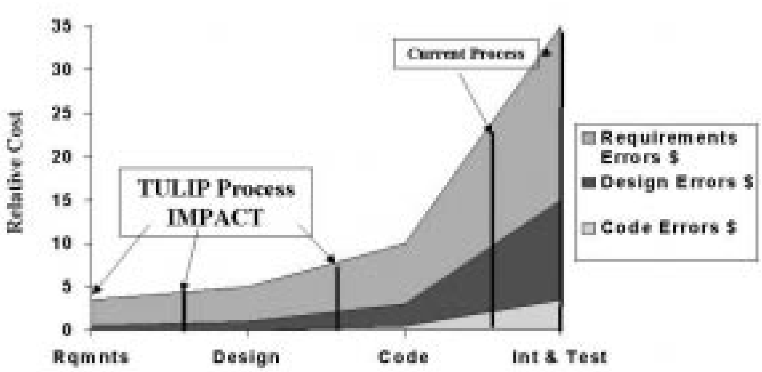

Figure 1. Relative cost of software error removal during development

The SLIRS overcomes MIL-STD/STANAG shortcomings because it is written in a specification language used to write detailed system specifications and coding requirements. The SLIRS defines a set of transactions for processing of messages received and transmitted by platforms implementing a TDL. Each transaction has defined stimuli, subsequent actions and outputs. Further requirements are defined within transactions for the host processing system, where additional processing is necessary to support message transmission or reception protocols. Defining information exchange as transactions at the level of definition in the SLIRS overcomes misinterpretation of MIL-STDs and STANAGs to improve interoperability.

PIDDs are the heart of the TULIP process. They are documents developed for each platform and are based on the SLIRS. Using the term "platform" in this context signifies "version of a system." For example, the Aegis weapon system has the basic TDS used by all U.S. Navy Aegis cruisers and destroyers. But because it is not feasible to upgrade all of the approximately 70 Aegis ships concurrently, eight different Aegis TDS versions are in service or are being developed. Thus, there will be eight different Aegis PIDDs.

PIDDs serve two different purposes. First, for a given platform, certain SLIRS requirements will not apply, due to the roles, missions and outfitting of the platform. SMEs, in concert with platform program managers, prepare a PIDD for each platform to be built. PIDDs are developed by consulting operational requirements documents, mission-need statements and the like to determine the subset of the complete TDL functionality the platform requires. For the required subset of TDL functionality, the SLIRS specifies how the platform will implement the TDL. The resulting PIDD is basically a red-lined version of the SLIRS that highlights each difference between the platform *requirements* and the baseline SLIRS.

Second, the differences described above are normally permanent differences because different platforms perform different roles and missions. These differences do not affect interoperability. PIDDs identify *deficiencies* in the platform implementation that require correction. SMEs usually identify these deficiencies in the system development process during review of the detailed platform specifications, and from reviewing the results of independent verification and validation and developmental testing, sometimes going all the way down into program code.

Deficiencies also can be identified during platform TDS integration, certification, interoperability testing and during system operation after entry into service. Such deviations may occur due to misinterpretation, funding or other programmatic limitations, or just due to programming error. But they inevitably occur. All deviations from SLIRS requirements are identified and documented in the PIDD, but with more detailed information about the impact of the deviation's impact on interoperability, priority and plans for correction, and rationale. When the two types of differences between the SLIRS requirements and actual platform implementation are identified, the PIDD then becomes a living document describing the actual implementation of all TDL capabilities in each platform.

PIDDs are all written in exactly the same format, using the formatted PIDD sheets comprising red-lined versions of the SLIRS. Thus, all differences between platforms can be readily discerned by side-by-side comparison, which amounts to overlaying the PIDDs for any two or more platforms. This then is the basis of the TDL expert systems analysis, which is the essence of the TULIP process, and which can inexpensively overcome the limitations of the very expensive TDL interoperability testing process. Obviously the analysis is not just the side-by-side comparison, saying "platform A and platform B are different." SME system analysts examine each difference in order to assess the impact on interoperability, and then report interoperability problems to the users and managers of the platforms. This aids greatly in prioritizing the funds to be allocated to correcting problems.

Detailed systems analysis by TDL experts is time-consuming and depends on the expertise of the analysts involved. Ways are being sought to automate this analysis process as much as possible. The ultimate goal is to place every single discrete SLIRS requirement into a database, such that compliance or non-compliance with each requirement by each platform can be entered into the database. Then, by determining the interoperability impact of each case of compliance versus non-compliance, and also by storing impact statements in the database, it may be possible to automate the bulk of the interoperability analysis. A feasibility investigation of this degree of automated analysis currently is underway.

Because PIDDs define only the differences from the SLIRS, these documents, although

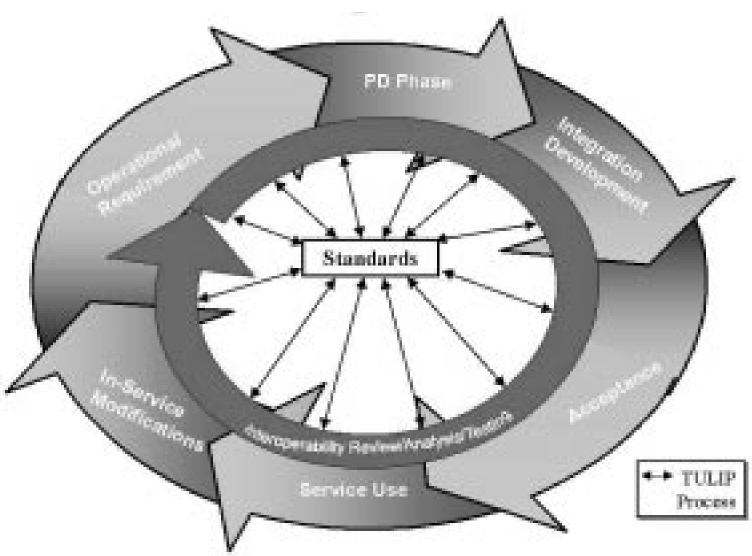

Figure 2. TULIP integration process

ideal for TDL expert systems analysis, are difficult for systems developers to use. To provide system developers with a single requirements document, a software tool known as the PIDD tool automatically merges the PIDD with the SLIRS to create a modified SLIRS that is specific to that platform. This is called the Platform SLIRS. The final two elements of the TULIP process as currently practiced are designed to greatly assist in the interoperability analysis of the PIDDs. These are an IOM and an IOA.

The United States and United Kingdom have developed a common method for detailing platform TDL implementations in a format that can be readily analyzed to determine at least 80-90 percent of potential interoperability issues across all platforms. The IOM is a Microsoft Access-based system that is used to specify, maintain, query and report on TDL implementations for all platforms currently implementing Link 16.

Rather than a database of all SLIRS requirements, the IOM is a set of functionally related questions about TDL implementation in the areas most likely to affect interoperability. The questions deal with a wide variety of TDL implementation, including data item implementation, protocol implementation and human-machine interface. The questions are answered as yes, no or explanation for each platform. The answers are ascertained from the PIDDs.

The IOM identifies potential IO problems and suggests solutions or workarounds by means of formatted IOAs. The IOM is a central repository for all IOAs, no matter how they are determined (for example, either by PIDD review, analysis of the IOM answers, interoperability testing or during actual operations). The IOM is distributed to operational units, providing access to full information on interoperability issues between platforms. For example, an airborne warning and control (AWACS) aircraft operator tasked with operating in a mixed force of fighters and other airborne early warning (AEW) aircraft can extract a listing of all known interoperability issues, including any known workarounds, that apply to this combination of platforms. The IOM also is distributed to technical agencies, allowing feedback to platform specifications and, where necessary, the SLIRS.

Conclusion

This paper has described the TULIP process and its key components, but it must reiterate that TULIP is not intended as a replacement for interoperability testing. Interoperability testing of military platforms is more important now than ever before, with the rapidly growing numbers of TDL-equipped platforms and the ever-increasing sophistication of military capabilities. This increase in numbers and capabilities makes a process such as TULIP essential to augmenting the existing interoperability test processes, enabling the growing number of platforms equipped with Link 16 to be certified prior to initial operational capability.

TULIP experts recognize that interoperability testing can never be 100-percent foolproof or complete, and the process works on that assumption. TULIP-like processes should be considered for augmentation of virtually any type of interoperability testing, as well as on any other form of system development and testing. Thus, it is sometimes referred to as the "management of imperfection." Through use of detailed TDL documentation, TULIP defines a common standard against which platforms can be specified and measured. The results of the TDL expert systems analysis are made available to the TDL community during system development, testing and in-service operation to provide users with full visibility of interoperability problems and workarounds. TULIP is applicable not only to new platforms but also to existing and legacy platforms. It enables documentation of differences from the common standard, thus enabling platforms to benefit from systems analysis and to define effective solutions. The result is much improved interoperability, achieved at minimum cost. ❑

Charles S. Hyatt is a member of the technical staff of Logicon, Incorporated, a Northrop Grumman company. He functions as the technical advisor to the Logicon staff, supporting the Navy Center for Tactical Systems Interoperability, San Diego, California. He is Logicon's technical manager for the TULIP process.

Andrew Hannam is a member of the technical staff of STASYS, Limited, Farnham, England. He has been closely involved in U.K. development of the TULIP process. He is currently participating with the U.S. joint services in developing the Joint Single Link Interface Requirement Specification for Link 16.